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Art. V.—*Metallic Replicas of Diffraction Gratings.*

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Owing to the scarcity of high quality Diffraction Gratings and inherent difficulties in their manufacture on a commercial basis, experimentalists have been encouraged to devise methods whereby replicas of existing Diffraction Gratings may be made. Probably the most widely known process is that invented by Thorpe, whereby a cast of the Grating is made in celluloid and subsequently transferred to a glass support of the requisite optical perfection. To obtain this cast, a solution of some nitrated cellulose material in amyl acetate is poured over the surface of the ruling, and after the solvent has evaporated sufficiently, the cast is separated from the original by immersion in water. With judicious care the celluloid film may be manipulated in the water and transferred to the glass support, after which it is set aside to dry. This method, or at least some modification of it, has been extensively practised by Ives, Wallace, and others (1). It is interesting to note that Ives invariably mounted the ruled side of the film towards the glass support, while Thorpe generally mounted it the other way round. Wallace, so far as the author is aware, made no distinction in his preference for either one side or the other.

It will be found, however, if the replica is mounted with the ruled side up the definition of the spectrum is not nearly so good as when it is mounted with the ruled side towards the optical surface. The reason for this is fairly obvious; in the former case any inequality in the thickness of the celluloid film introduces corresponding irregularities into the ruled surface, whereas in the latter case the truth of the ruled surface of the replica is preserved by the optical flat on which it is mounted.

The celluloid replica acts best as a transmission grating, but if the ruled side be mounted face out it may be converted into a reflection grating replica by cathodically depositing platinum or some other metal on it, so as to make the surface reflecting, as described by Gehrcke and Leithauser (2), but it should be borne in mind that in order to obtain the same definition with a grating of this type, the optical surface must be at least twice as accurate.

It is possible to make metallic grating replicas by this method which behave reasonably well in the first order, but in higher orders the definition, and of course the resolving power, fall far short of the original ruling. To overcome this difficulty, Dr. Anderson (3) proposed an ingenious method.

A celluloid replica is first made, and then transferred, ruled side in, on to a carefully prepared optical surface which has been covered with a thin uniform film of resinous material. When dry the whole is gently warmed so as to enable the resin to flow and take a cast of the celluloid replica. On cooling it will be found that the celluloid replica can be stripped off, leaving behind an impression in the resinous film which may be subsequently covered with a reflecting metallic surface by cathode disintegration in a vacuum. A defect of this method seems to be that the shape of the grooves is not well preserved in the final cast, and consequently the intensity and concentration of the diffracted light in a given direction are incompatible with the original ruling.

Other attempts worthy of some note here, because they are essentially different from those already mentioned, are those of Lord Rayleigh and Professor Quincke. Rayleigh actually succeeded in producing replicas by means of photographic contact printing; while Professor Quincke chemically deposited silver on a glass original, and then gradually increased the thickness of this film by electro-deposition of copper until it was strong enough to be peeled off.

Lord Rayleigh (4) found that Professor Quincke's replicas deteriorated after a time, owing apparently to insufficient thickness of the silver film, or perhaps from want of adhesion between the silver and the copper. This defect Rayleigh endeavoured to remedy by increasing the thickness of the silver film, not with copper, but with silver itself. In this he was partially successful, but he mentions that the surface of these replicas suffered from want of flatness, and he came to the conclusion that the use of such gratings must be limited to cases where brilliancy of the spectra is required, and resolving power is not essential. In the papers referred to, Rayleigh describes at considerable length his photographic method, and draws attention to certain inherent defects in the process. Quite apart from these defects, Rayleigh's photographic process is very limited, for it is obviously not possible to reproduce the carefully shaped grooves of the original ruling, which are so essential.

In various publications quite a number of references will be found to the manufacture of Diffraction Grating Replicas, but the processes described seem to differ only in modus operandi from those already alluded to here.

The main purpose of this paper is to describe a novel method whereby a reflection grating replica is obtained direct from the original grating. The replica obtained by the method seems to differ but little from the original ruling in resolving power, and at the same time gives remarkably brilliant spectra. When the replica and the original (silvered) are arranged on the spectroscope so as to enable a fair comparison of

the spectra they produce being made, it will be seen that as regards definition it is difficult to discriminate between the two, but the intensity of the light from the replica seems to rival that from the original ruling. The reason for this seems to be mainly on account of the difference in reflecting power of the front and back surface of the metallic film.

The method of producing such a replica is as follows:—The original ruling of glass is silvered by the Brashear process, and is then carefully washed and dried. If nickel, gold, platinum, or any other metal is desired, the original is plated by cathode disintegration in a vacuum. The thickness of the deposit should be about 0.0001 mm. A solution of celluloid in amyl acetate is then poured over the metallic film and set aside to dry slowly. The celluloid film is then covered with a film of vacuum sealing wax, or balsam, and then a cut is made by means of a sharp knife all round the ruled area, and the unrequired margin is removed. It will be found that the celluloid easily comes away, bringing with it the metallic deposit. The next step is to mount the replica, and this is accomplished in the following manner:—An appropriate optical flat is prepared (a piece of good quality plate glass will suffice), and this is laid in contact with the back of the replica and very light pressure applied. The whole is then gently and uniformly heated in an oven until the wax or balsam adheres to the glass support. When cold it will be found that the replica generally separates from the original without difficulty. If the separation is troublesome, it is probably because the adhesive has oozed out and cemented the edge of the replica to the original. If this be the case the support should be separated after gentle warming, the original cleaned with amyl acetate and a fresh start made.

An alternative method which has been found satisfactory is to support the replica on a block of wax. This is accomplished by raising a small metal frame around the replica, and subsequently casting the wax support on to it. For this purpose the most suitable wax yet found is Picene Vacuum Sealing Wax, and also that used in the manufacture of some kinds of cylinder phonograph records. Care, of course, must be taken to cool the whole very slowly, otherwise the perfection of the optical surface of the replica departs considerably from that of the original ruling.

LIST OF REFERENCES.

1. *Astrophysical Journal,* 22, 1905, p. 123; 23, 1906, p. 96.

2. *Verhandlungen der Deutschen Physicalischen Gesellschaft,* 1906.

3. *Astrophysical Journal,* 31, 1910, p. 171.

4. *Phil. Mag.* 11, 1881, p. 196; xlvii., 1874, p. 81.